MODULE OVERVIEW

HURRICANES

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Document Contents:

Vista Overview

The followings activities use modern meteorological and remote-sensing data to study hurricanes and some of their hazardous effects. **Learning Experience 1 – Weather Tracker: A Team Approach to Studying Hurricanes** uses weather data collected by the National Oceanic and Atmospheric Administration (NOAA) to track an Atlantic hurricane that occurred in 2001. **Learning Experience 2 – Landslides and Flooding in Honduras: Results of Hurricane Mitch** uses a map of the capital city of Tegucigalpa, Honduras, that was generated from light detection and ranging (lidar) data to show how the El Berrinche landslide caused extensive flooding in the city in November 1998.

- Students will tabulate and graphically summarize modern meteorological data to learn about frequency of hurricanes.
- Students will use modern meteorological data to track a hurricane in a mock "Weather-Tracker" simulation. Students will assume the role of a team of meteorologists to follow Hurricane Erin—a 2001 tropical cyclone that moved up the Atlantic seaboard.
- Students will be introduced to lidar, which is an innovative technology used to generate digital maps, to understand the importance of having accurate maps for disaster management.
- Students will learn how to use ArcExplorer2—a GIS (Geographic Information Systems) application.
- Students will observe flooding caused by the El Berrinche landslide in Tegucigalpa, Honduras in the aftermath of Hurricane Mitch. They will develop an appreciation of the danger that hurricanes present to people and property.

Correlation to Texas and National and Education Standards

Correlation to Texas Essential Knowledge and Skills (TEKS)

We recommend that teachers select one or two of the TEKS listed to emphasize in the learning activities and not attempt to teach all the TEKS listed. High school science TEKS are available on the Texas Education Agency Website at http://www.tea.state.tx.us/rules/tac/.

	TEKS									
Discipline	2	3	4	8	10	12	13	19	21	23
IPC	A,B,C,D	C	A							
Environmental Systems	A,B,C,D	C		A						
Physics	B,C,D,E	A,C	A							
GMO	A,B,C,D	A,B,C,D			B	C	A,B			
World Geography		A,B		C				A,B	A,B,C,E	A,B,C,D

Correlation to National Science Education Standards Grades 9-12

Content Area	Standard	Correlation
Unifying Concepts and Processes	Evidence, models, and explanation	Learners make observations, manipulate data, and propose explanations.
Science as Inquiry	Abilities and understanding of scientific inquiry	Learners explore the relationships between wind speed and atmospheric pressure to explain the intensity of hurricanes/tropical storms characteristics.
Earth and Space Sciences	Energy in the Earth system and the origin and evolution of the Earth system	Learners develop an understanding of energy transfer and the dynamic forces that influence global climate by focusing on the particular role of hurricanes in transferring heat energy from low to high latitudes.
Science and Technology	Understanding about science and technology	Learners develop an understanding of lidar and GPS technology; they also learn how to use GIS to manipulate digital elevation models derived from lidar datasets of an area devastated by Hurricane Mitch.
Science in Personal and Social Perspectives	Natural hazards	Learners develop an understanding of how hurricanes can cause catastrophic damage to people and property through landslides and flooding.
History and Nature of Science	Science as a human endeavor	Learners work with the types of tools (in this case one example is GIS) and real data to draw conclusions in a similar manner to that of real scientists.

Background Information for Teachers

Did You Know?

Hurricane Facts

According to the **National Hurricane Center**, hurricane season in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico lasts from June 1st through November 30th. During this time there is an increased risk of damage from tropical cyclones in the Caribbean Islands, Central America, Mexico, and states along the Gulf of Mexico and the Atlantic Coast of the United States.

Hurricanes are a category of tropical cyclone. A **tropical cyclone** is defined as an atmospheric low-pressure system fueled by warm ocean waters rising into the atmosphere. Tropical cyclones are closed circulation systems that rotate in a counter clockwise direction in the northern hemisphere. A phenomenon called the **Coriolis effect** is what controls the direction of tropical cyclone rotation. Section 4.0 in the following Web reference (http://www.physics.ohiostate.edu/~dvandom/Edu/newcor.html) has a good description of why tropical cyclones rotate this way. Another good place to read details about how tropical cyclones form is http://www.srh.weather.gov/srh/jetstream/tropics/tc.htm.

Tropical cyclones are categorized on the basis of maximum sustained wind speed as a tropical depression, tropical storm, or hurricane. A **tropical depression** has sustained winds up to 39 mph (34 kts or 63 km/hour); a **tropical storm** has maximum sustained winds between 39 and 74 mph (63 and 119 km/hr); a **hurricane** has sustained winds over 74 mph (64 kts or 119 km/hr). The category of a tropical cyclone will often change many times during the storm as a result of changes in temperature and moisture conditions in the atmosphere. If maximum sustained winds drop below 39 mph (63 km/hr) a tropical depression will become simply a low-pressure area. If a storm moves out of the tropics (above 23° latitude), it becomes an **extratropical system**.

Once a tropical cyclone reaches the level of a tropical storm, it is given a name. A table of possible names of tropical storms and hurricanes between 2002 and 2007 is included in the **Lecture Supplements** section. Details about the Saffir-Simpson Hurricane Scale are also in the **Lecture Supplements** section.

The Saffir-Simpson Hurricane Scale is a disaster-potential scale that assigns hurricanes to five categories, with category 5 having the most dangerous conditions and highest potential risk. It is used to give emergency managers and weather forecasters an estimate of the potential property damage and flooding expected along the coast during a hurricane. The scale was formulated in 1969 by Herbert Saffir, a consulting engineer, and Dr. Bob Simpson, director of the National Oceanographic and Atmospheric Administration's National Hurricane Center: http://www.aoml.noaa.gov/general/lib/laescae.html and http://www.srh.noaa.gov/hgx/tropical/scale.htm.

Two categories of alert are associated with hurricanes: Hurricane Watch and Hurricane Warning. A **Hurricane Watch** specifies that hurricane conditions are possible within 36 hours; a **Hurricane Warning** means that a hurricane is expected to hit a particular coastal area within 24 hours. Information about tropical cyclones is collected using high-flying aircraft that drop *sondes* (instruments that can measure and transmit atmospheric data) directly into the cyclones (http://www.aoml.noaa.gov/hrd/aircraft.html). Examples of these types of data are used in **Learning Experience 1**.

The U.S. Department of Homeland Security/Federal Emergency Management Agency has published a document titled *Surviving the Storm, A Guide to Hurricane Preparedness* (See Hurricane Safety section in **Lecture Supplements**). In this document dangers associated with and damage resulting from high winds and flooding along the Atlantic Seaboard and the Gulf of Mexico in the United States are discussed. You will find in **Learning Experience 2** that landslides are another severe risk associated with hurricanes.

Hurricane Mitch

From October 27 through November 1, 1998, Central America was devastated by Mitch, a category 5 hurricane on the **Saffir-Simpson Hurricane Scale**, with winds up to 155 mph. **Hurricane Mitch** was responsible for over 9,000 deaths, making it one of the deadliest Atlantic tropical cyclones in history and comparable to the great Galveston storm of 1900. In **Honduras**, the human toll was estimated at 5,000 deaths. Whole villages were washed away, and an estimated 70 to 80 percent of the transportation infrastructure was destroyed. At least 70 percent of the crops were destroyed; an estimated $900 million loss. Honduras will be rebuilding the housing and infrastructure destroyed by Hurricane Mitch for many years (http://www.aoml.noaa.gov/hrd/Storm_pages/mitch1998/index.html).

Hurricane Mitch went ashore in Honduras near the town of Santa Rosa de Aguán. Following is an account of the fate of one family living in that area at the time (Davies, 2000, p. 202):

> One woman, a thirty-two-year-old school teacher named Isabela Arriola from the nearby village of Barra de Aguan, sought refuge on the roof of a neighbor's house about a mile from the sea. It wasn't far enough away; with her husband and their three children, Arriola was swept into the water. They clung to the side of a small boat for a while, but her husband and two of the children were washed away; Arriola's youngest son was pulled from her arms by the power of the waves not long afterward.
>
> In a feat of endurance as much tragic as epic, Arriola somehow fashioned a makeshift raft out of tree roots, branches, and a piece of wooden board. Surviving on a few pineapples, oranges, and the milk from a coconut she saw floating past her, she was adrift in the sea for six days. When she was picked up by a helicopter from a British naval vessel, HMS *Sheffield*, she was fifty miles out from shore.

During flooding in the city of Choluteca, Honduras, cars were swept from parking lots into the river, which was flowing at a rate of ~11,000 cubic feet per second. Debris was transported as far as the **Gulf of Fonseca**, which is located approximately 50 miles downstream from Choluteca on the Pacific side of the country. Unfortunately, cars with passengers were also swept off city streets and similarly transported downstream (Davies, 2000).

In February and March of 2000, the Bureau of Economic Geology (BEG) at the University of Texas at Austin, the United States Geological Survey (USGS) and Optech Inc. of Toronto, Canada, collaborated to map 15 Honduran municipalities using a new technology called **airborne lidar**. BEG scientists worked with personnel from the USGS, the U.S. Agency for International Development (USAID), the Honduran Instituto Geográfico Nacional (IGN), the U.S. National Geodetic Survey (NGS), and other groups to provide the lidar and ground-based global positioning system (**GPS**) information required for the Hurricane Mitch mapping project in Honduras.

Airborne lidar mapping utilizes laser ranging, inertial motion, and GPS technologies to generate three-dimensional, digital topographic maps. After Hurricane Mitch, the rivers in Honduras had changed course so drastically that entirely new maps needed to be produced. Lidar mapping was one of the technologies used to generate new maps of small portions of the country. **Learning Experience 2** uses a map of **Tegucigalpa**, the capital city of Honduras, generated from lidar data; to demonstrate how a major landslide, the El Berrinche landslide, caused extensive flooding in the city in November 1998.

Resources

Web sites

1. National Oceanographic and Atmospheric Administration Hurricane FAQ: http://www.aoml.noaa.gov/hrd/Landsea/deadly/
2. The USGS report that summarizes Hurricane Mitch: http://mitchnts1.cr.usgs.gov/
3. The USGS report that focuses on El Berrinche landslide: http://mitchnts1.cr.usgs.gov/
4. National Oceanographic and Atmospheric Administration information on Hurricane Mitch http://www.aoml.noaa.gov/hrd/Storm_pages/mitch1998/index.html
5. National Hurricane Center Archive for past hurricanes: http://www.nhc.noaa.gov/pastall.shtml

Videos

1. Storm Force: Hurricanes, Koch Vision, 1999.
2. Nova: Hurricane! WGBH Boston, 1989.

Books

1. Davies, Pete, Inside the Hurricane, Face to Face with Nature's Deadliest Storms: Henry Holt and Company, LLC, 2000.
2. Hall-Wallace, M. K., Walker, C. S., Kendall, L. P., and Schaller, C. J., 2004, Exploring Tropical Cyclones: GIS Investigations for the Earth Sciences: Florence, KY, Brooks/Cole Publishers, 78 p.+CD-ROM.

Learning Experiences

Learning Experience 1: *Weather-Tracker: A Team Approach to Studying Hurricanes*

This Learning Experience contains four parts. The class should be split up into four groups, and one part should be given to each group. When all groups are finished, each will present its findings to the rest of the class.

Note: As an alternative approach, each team of students can be given a copy of all four parts of Learning Experience 1. This approach will encourage the students to compare their findings in a team setting rather than a class presentation setting. The educator may adopt either approach depending on what works best with his or her students. This activity can be repeated with more recent hurricane data by visiting the National Hurricane Center Web page to retrieve updates: http://www.nhc.noaa.gov/pastall.shtml.

The four parts are each presented in the context of a memorandum from a director of the National Hurricane Center. Students will assume the role of meteorologists who are assigned to study Hurricane Erin—a 2001 cyclone that traveled from the western coast of Africa, past the Caribbean, along the Atlantic coast, and up to Greenland. Following is a brief description of each part of Learning Experience 1.

Part 1 for Student Group 1: Historical Occurrence Study asks students to summarize the data from Table 1 by filling in the blanks in Tables 1A, 1B, and 1C. Students are then asked to plot data on the appropriate histogram (**See Learning Experience 1: Student Handout, pages 2-4**). The objective of this exercise is for students to learn when Atlantic tropical storms occur and how long they typically last.

Part 2 for Student Group 2: **Storm Tracking** asks students to track the path of the hurricane on a map using data from Table 2 (**See Learning Experience 1: Student Handout, pages 5-7**). Students plot the position of the tropical cyclone and color code the path according to storm classification (e.g., tropical depression, tropical storm, low-pressure area, reformed tropical storm, hurricane, or extratropical storm) using the map and color key provided on page 7. The objective of this exercise is to understand how the rate of tropical cyclone movement and the paths they follow can change quickly.

Part 3 for Student Group 3: Wind Speed Tracking asks students to plot wind speed data from Table 3 on the histogram template, both of which are provided on page 9. Students are also asked to color-code the cyclone positions by wind speed using the map and color key provided on page 10 (**See Learning Experience 1: Student Handout, pages 8-10**). The objective of this exercise is to identify how winds increase and decrease as a hurricane develops and dissipates.

Part 4 for Student Group 4: Atmospheric Pressure Tracking asks students to plot barometric pressure data given in Table 4 on the histogram template, both of which are provided on page 12. Students are also asked to color-code the cyclone positions by barometric pressure using the map and color key provided on page 13 (**See Learning Experience 1: Student Handout, pages 11-13**). The objective of this exercise is to identify how changing pressures cause air masses swell and contract as a cyclone moves.

Note: Students will need to know the definition of a knot - 1nautical mile per hour, which is abbreviated as kt (singular) or kts (plural). Refer to the following Web page to find out how to convert miles per hour (mph) to kts. http://www.grc.nasa.gov/WWW/K-12/WindTunnel/Activities/knots_vs_mph.html.

Time Frame
2 hours

Materials
- Colored pencils
- Calculators
- Graph paper
- Overhead transparencies and markers

Advanced Preparation for Learning Experience 1

- Have students prepare blank templates for histograms using either graph paper or overhead transparency. Example summary tables and histogram templates are provided in the **Student Handout**.
- EDUCATOR SHOULD READ THROUGH THE **Procedure for Guided Inquiry** BEFORE PRESENTING MATERIAL TO THE STUDENTS.

Procedure for Guided Inquiry – Learning Experience 1

1) The educator should construct a T-chart on the board, ask students what they know about hurricanes, and fill in the left side of the chart with students' answers. Then the educator can explain that he or she will ask the students to provide information to fill in the right side of the chart after they finish the four parts of **Learning Experience 1**.

2) The educator needs to separate the class into four groups and give each group its own portion of the **Student Handout** (i.e., Group 1 – Historical Occurrence Study; Group 2 – Storm Tracking; Group 3 – Wind Speed Tracking; and Group 4 – Atmospheric Pressure Tracking).

3) As the students move through the exercise, the educator should address questions from the individual student groups.

4) As the students finish their respective exercises, they should be preparing a brief presentation on their findings to share with the class.

5) Educator should lead the **Formative/Authentic Assessment.**

6) After completion of the Formative/Authentic Assessment, the educator may have the students complete the Summative Assessment questions at the end of the **Learning Experience 1 Student Handout**.

Formative/Authentic Assessment (exercise to gauge students' learning):

Students should present the results of their exercise to the class. Group members should sketch their graphs on an overhead transparency. The wind speed and the pressure teams should overlay their graphs in order to explain the relationship between these variables. In particular, they should notice that increasing wind speeds correspond to a drop in atmospheric pressure inside the storm. After all of the groups have presented their findings, the educator should lead a discussion to synthesize all of the students' input and assess their understanding of hurricanes. Following is a list of possible discussion topics:

- How did wind speed and pressure change as Hurricane Erin formed?
- Was Hurricane Erin a typical hurricane, historically speaking?
- Did the course of Hurricane Erin ever present any danger to people?

- Would you have issued a warning to people in the Caribbean? Hint: look at the path of the first eight data points.

Learning Experience 2: Landslides and Flooding in Honduras: Results of Hurricane Mitch

This Learning Experience uses a geographic information systems (GIS) software package to get students to understand how a hurricane can cause catastrophic damage to people and property through landslides and flooding; it requires a PC computer running Windows98 or above. The GIS software, ArcExplorer 2, can be downloaded from the Internet Website of a company called Earth Systems Research Institute, Inc. (ESRI). The Web address for downloading ArcExplorer is http://www.esri.com/software/arcexplorer/. ArcExplorer is a GIS software package that allows you to display and manipulate maps and data layers on a computer. The name of the file you will download is **ae2setup.exe**. Once the educator has ae2setup.exe installed on the hard drive of each computer to be used, double-click the file name to install the program. These steps require the educator to have access to "administrator privileges" for computers on which the program is to be installed.

Two types of data files are needed for Learning Experience 2: a base map file that ends with ".tif" and shape files that end with " .sbn, .sbx, .shp, .shx, and .dbf." The base map used in Learning Experience 2 is called **teguz.tif**; the ".tif" file extension stands for tag image file format. The shape files are called: **new_river.*; debris scar.*; dam2.*; WL930m.*; and WL935m.***. The asterisk at the end of the file name means that each shape file exists as five separate files with different endings. All of the data files are zipped into a file called **mitch.zip**.

The base map file is an approximately 3 km × 3 km digital image of an area in Tegucigalpa, Honduras, that was generated using a **lidar** dataset. An intermediate product generated from the lidar data set is a digital elevation model (DEM). A DEM can look just like a detailed map, and it can give you x, y, and z coordinates of each point when you click on it using advanced GIS programs. You will not be able to view coordinates using ArcExplorer, but you can see the coordinates if your school has purchased one of the more elaborate GIS ESRI programs, ArcView or ArcGIS.

Time Frame
1 hour

Materials
- A computer running a Windows98 or above operating system
- ArcExplorer2 software installed on the computer
- Data files from http://www.ig.utexas.edu/outreach/activities/cat/hurricanes/mitch.zip

Advanced Preparation

- Print the “notes” pages from the PowerPoint presentation, hurricane_mitch_lidar.ppt, prior to starting the Learning Experience. The “notes” are not visible when the PowerPoint file is viewed in presentation mode. Otherwise, the educator will not know what to say about each of the slides during presentation to the students.
- The educator should obtain Administrator privileges or request IT personnel to download and install ArcExplorer2. It is critical that the installation is done in its entirety. Do not do a partial installation.
- The educator should familiarize himself or herself with GIS technology enough to explain it to students if necessary.
- The educator should obtain the necessary data files needed to load into ArcExplorer2 either by downloading from the Web or from CD. The file **mitch.zip** will need to be unzipped and put into a working directory where the students can find the component data files.
- WE ENCOURAGE EDUCATORS TO HAVE ALL SOFTWARE AND DATA FILES DOWNLOADED AND INSTALLED ON STUDENT COMPUTERS AT LEAST 1 DAY IN ADVANCE.
- EDUCATOR SHOULD READ THROUGH THE **Procedure for Guided Inquiry** BEFORE PRESENTING MATERIAL TO THE STUDENTS.

Procedure for Guided Inquiry

1. Begin by asking students whether they have ever witnessed a hurricane or a tropical storm. If so, ask them whether they remember the name of the cyclone or category of the hurricane. The educator may need to review the contents of **Learning Experience 1** or the **Lecture Supplements** to familiarize himself or herself with types of tropical cyclones and the categories of hurricanes.
2. Give students some examples of really big hurricanes that have occurred in history. For example, the Great Hurricane of 1900 that destroyed Galveston Island, Texas, and Hurricane Mitch that devastated Honduras, Central America, in 1998.
3. Show PowerPoint presentation (**hurricane_mitch_lidar.ppt**) to give background on characteristics of and damage caused by Hurricane Mitch in Honduras and a brief introduction to lidar technology. The PowerPoint file contains both slides and notes so that the educator will know what to say about each slide.
4. Review topics covered in the **“Did You Know?”** section earlier, especially GIS and lidar technology.
5. Give students their copies of the **Learning Experience 2 Student Handout.** If possible, the educator should print the handout in color so that students can look at an example of a map generated using **lidar** on pages 6-8. The educator should also ask students whether they are familiar with GIS computer programs and discuss if necessary.

6. If each student has access to a computer, **Learning Experience 2** is best completed individually. If not, the educator should try to limit groups to 2-3 students per computer. The educator will need to tell students where the data files are located OR have students unzip the mitch.zip file containing the data files and put it where they can find it after they begin the GIS exercise.
7. Give students approximately 30 minutes to complete the GIS activity (pages 2-4 in the Student Handout).
8. Educator should lead the **Formative/Authentic Assessment**
9. After completion of the Formative/Authentic Assessment, the educator should have the students complete the Summative Assessment questions on page 5 of the **Learning Experience 2 Student Handout**.

Formative/Authentic Assessment <u>(exercise and questions to gauge students' learning)</u>

- The educator should query students about the different ways that hurricanes can cause catastrophic damage, for example, wind damage, flooding, and landslides.
- Present the following question to students: If water is flowing over a bridge, is it O.K. to assume that the car is heavy enough to drive over that bridge anyway? See page 11 in **Lecture Supplements**.
- The educator should have students look on the Worldwide Web for information on lidar technology and have them give examples of other uses for lidar besides mapping.
- Critical Thinking Question for the educator to pose to students: Why is GPS such a critical component to lidar? *Answer: It does no good to make a map using a laser to measure ranges between an aircraft and the ground if you do not know the exact position of the plane with respect to the ground.*
- <u>Presentation on basic principles of lidar and GPS</u> by Rebecca C. Smyth or Roberto Gutierrez (Jackson School of Geosciences workshops only).

Acknowledgements

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Appendix 1. Correlation to the Texas Essential Knowledge and Skills (Integrated Physics and Chemistry (IPC), Environmental Systems; Physics; Geology, Meteorology, and Oceanography (GMO); and World Geography)
(http://www.tea.state.tx.us/rules/tac/**)**

	TEKS									
Discipline	2	3	4	8	10	12	13	19	21	23
IPC	A,B,C,D	C	A							
Environmental Systems	A,B,C,D	C		A						
Physics	B,C,D,E	A,C	A							
GMO	A,B,C,D	A,B,C,D			B	C	A,B			
World Geography		A,B		C				A,B	A,B,C,E	A,B,C,D

Chapter 112. Texas Essential Knowledge and Skills for Science
Subchapter C. High School

§112.42. Integrated Physics and Chemistry.

(c) Knowledge and skills.

(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:

(A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(B) collect data and make measurements with precision;

(C) organize, analyze, evaluate, make inferences, and predict trends from data; and

(D) communicate valid conclusions.

(3) Scientific processes. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(C) evaluate the impact of research on scientific thought, society, and the environment;

(4) Science concepts. The student knows concepts of force and motion evident in everyday life. The student is expected to:

(A) calculate speed, momentum, acceleration, work, and power in systems such as in the human body, moving toys, and machines;

§112.44. Environmental Systems.

(c) Knowledge and skills.

(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:

(A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(B) collect data and make measurements with precision;

(C) organize, analyze, evaluate, make inferences, and predict trends from data; and

(D) communicate valid conclusions.

(3) Scientific processes. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(C) evaluate the impact of research on scientific thought, society, and the environment;

(8) Science concepts. The student knows that environments change. The student is expected to:

(A) analyze and describe the effects on environments of events such as fires, hurricanes, deforestation, mining, population growth, and municipal development;

§112.47. Physics.

(c) Knowledge and skills.

(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:

(B) make quantitative observations and measurements with precision;

(C) organize, analyze, evaluate, make inferences, and predict trends from data;

(D) communicate valid conclusions;

(E) graph data to observe and identify relationships between variables;

(4) Science concepts. The student knows the laws governing motion. The student is expected to:

(A) generate and interpret graphs describing motion including the use of real-time technology;

§112.49. Geology, Meteorology, and Oceanography.

(c) Knowledge and skills.

(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:

(A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(B) collect data and make measurements with precision;

(C) organize, analyze, evaluate, make inferences, and predict trends from data; and

(D) communicate valid conclusions.

(3) Scientific processes. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(A) analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information;

(B) draw inferences based on data related to promotional materials for products and services;

(C) evaluate the impact of research on scientific thought, society, and the environment;

(D) describe the connections between geology, meteorology, oceanography, and future careers;

(10) Science concepts. The student knows the interactions that occur in a watershed. The student is expected to:

> (B) analyze the impact of floods, droughts, irrigation, and industrialization on a watershed; and

(12) Science concepts. The student knows the characteristics of the atmosphere. The student is expected to:

> (C) determine the impact on the atmosphere of natural events and human activity.

(13) Science concepts. The student knows the role of energy in governing weather and climate. The student is expected to:

> (A) describe the transfer of heat energy at the boundaries between the atmosphere, land masses, and oceans resulting in layers of different temperatures and densities in both the ocean and atmosphere;
>
> (B) identify, describe, and compare climatic zones;

Chapter 113. Texas Essential Knowledge and Skills for Social Studies
Subchapter C. High School

§113.34. World Geography Studies

(c) Knowledge and skills.

(3) Geography. Such as student understands how physical processes shape patterns in the physical environment (lithosphere, atmosphere, hydrosphere, and biosphere), including how Earth-Sun relationships affect physical processes and patterns on Earth's surface. The student is expected to:

> (A) attribute occurrences of weather phenomena and climate to annual changes in Earth-Sun relationships; and
>
> (B) describe physical environment of regions and the physical processes that affect these regions such as weather, tectonic forces, wave action, freezing and thawing, gravity, and soil-building processes.

(8) Geography. The student understands how people, places, and environments are connected and interdependent. The student is expected to:

(C) describe the impact of and analyze the reaction of the environment to abnormal and/or hazardous environmental conditions at different scales such as El Niño, floods, droughts, and hurricanes;

(19) Science, technology, and society. The student understands the impact of technology and human modifications on the physical environment. The student is expected to:

(A) evaluate the significance of major technological innovations, including fire, steam power, diesel machinery, and electricity that have been used to modify the physical environment; and

(B) analyze ways technological innovations have allowed humans to adapt to places shaped by physical processes such as floods, earthquakes, and hurricanes.

(21) Social studies skills. The student applies critical-thinking skills to organize and use information acquired from a variety of sources including electronic technology. The student is expected to:

(A) use historical, geographic, and statistical information from a variety of sources such as databases, field interviews, media services, and questionnaires to answer geographic questions and infer geographic relationships;

(B) analyze and evaluate the validity and utility of multiple sources of geographic information such as primary and secondary sources, aerial photographs, and maps;

(C) construct and interpret maps to answer geographic questions, infer geographic relationships, and analyze geographic change;

(E) use a series of maps, including a computer-based geographic information system, to obtain and analyze data needed to solve geographic and locational problems.

(23) Social studies skills. The student uses problem-solving and decision-making skills, working independently and with others, in a variety of settings. The student is expected to:

(A) plan, organize, and complete a group research project that involves asking geographic questions; acquiring, organizing, and analyzing geographic information; answering geographic questions; and communicating results;

(B) use case studies and geographic information systems to identify contemporary geographic problems and issues and to apply geographic knowledge and skills to answer real-world questions;

(C) use a problem-solving process to identify a problem, gather information, list and consider options, consider advantages and disadvantages, choose and implement a solution, and evaluate the effectiveness of the solution; and

(D) use a decision-making process to identify a situation that requires a decision, gather information, identify options, predict consequences, and take action to implement a decision.